Taxila Central College - Horana

01 E II

General Certificate of Education (Adv. Level) Examination - 2025

Physics II

Grade 13

3rd Term Test - 2026 July

Time : 3 hrs.
Additional reading time 10 minutes

PART B - ESSAY

Answer four questions only.

05. The figure shows a jet ski moving on water. The mass of the jet ski along with the rider is 250 kg

(a) i. The engine of the machine uses a propiller to eject water backward. The jet-ski gets propulsion from its engine. Explain the forward motion of the jet-ski due to the ejection of water based on Newton's laws of motion.

ii. If the jet-ski engine ejects water at a rate of 15 kg per second with a velocity of 20 m s^{-1}, calculate the propulsive force produced.

iii. If the resistive force exerted by the water on the jet-ski is 100N, calculate the forward acceleration of the jet -ski when the speed of the water ejection remains unchanged.

(b) The jet-ski mentioned above now travels in a cicular path of radius 20 m with a constant speed of 10 m s^{-1}

Let θ be the angle jet-ski makes with center of the circle.

i. Calculate the centripetal force acting on the jet - ski.

ii. At this instance, what is the angle θ at which the jet-ski is tilted ? Consider the resultant reaction force exerted by water as R.

iii. Explain how to maintain equilibrium while increasing the speed of the jet-ski by means of physics.

(c) A water skier with a mass 85 kg is being pulled by a jet-ski using a tow rope.

i. Draw free- body diagrams showing the forces acting on the wate skier and the water ski board.
(Neglect mass of the ski board.)

ii. Calculate the immersed volume of the ski board while the skier is standing on it. The density of water is 1000 kg m^{-3} .

iii. If the jet-ski in (a) above ejects water at a rate of 15 kg s^{-1} with a velocity of 20 m s^{-1}. The resistive force on the player by water is 1/10 of his weight

I. Calculate forward acceleration of the skier.

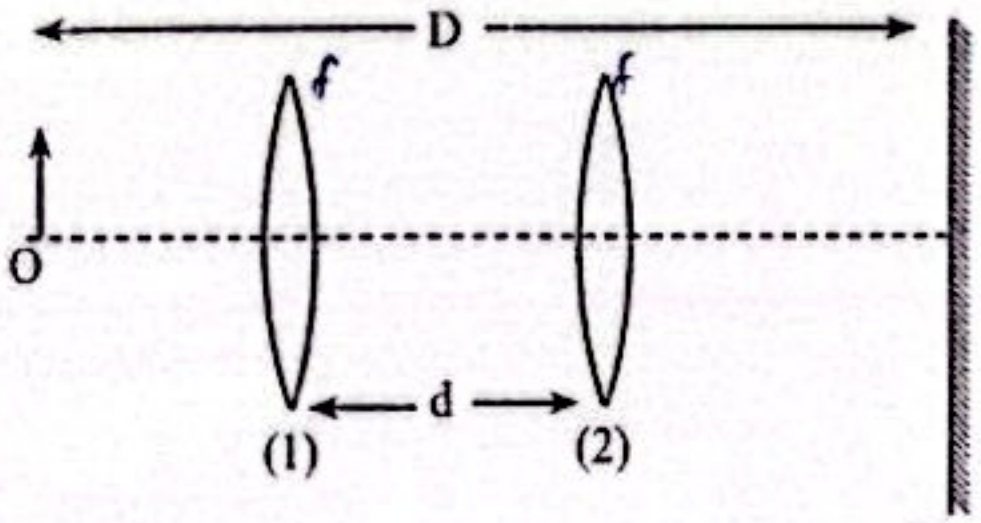
II. Find the tension of the rope attached to the skier.

III. Calculate the drag force exerted by the water on the skier.

(d) i. The jet-ski pulls the skier for 100 m with a constant force of 400 N. Calculate the work done.

ii. If the skier reaches a velocity of 10 m s^{-1} in 100 m starting from rest, calculate the work done against the drag force.

06. (a)



A fixed object O and fixed screen C are kept D distance apart as shown in the figure. As a convex lens is moved from object towards the screen, it forms images on the screen at two positions (1) and (2) which are d distance away form each other.

i. Write the condition that must be met in terms of f and D to obtain an image of object O on the screen, where f is the focal length of the convex lens.

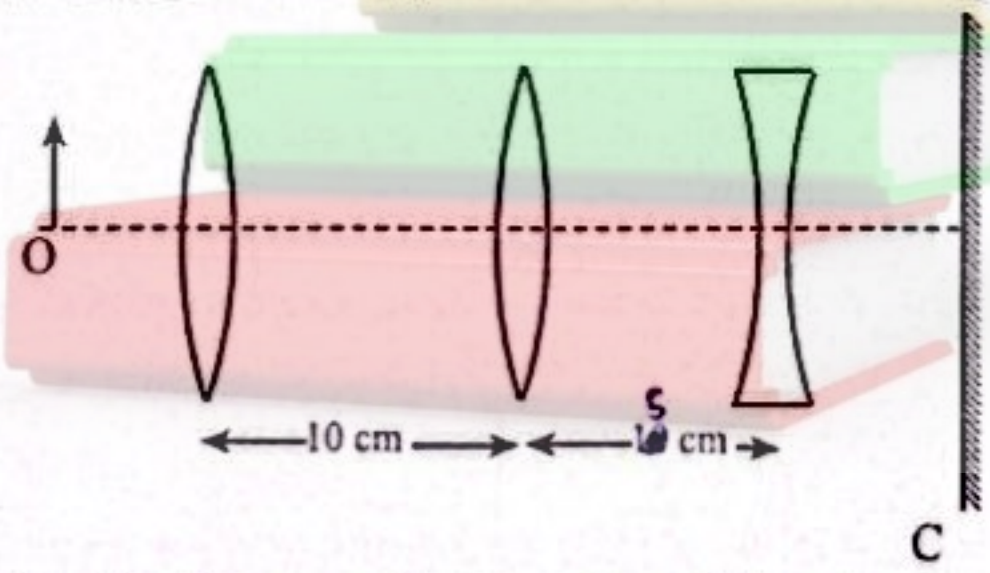
ii. Obtain an expression for the focal length (f) of the convex lens in terms of D and d.

iii. If D = 50 cm and d = 30cm calculate the focal length

iv. Calculate the object distances corrosponding to the positions (1) and (2) of the convex lens.

v. Determine the type and power of the lens that should be combined with the above convex lens to obtain an image on the screen that is equal in size to the object.

(b) Now the convex is placed between the object and the screen so that the object distance is exactly equal to the minimum distance obtained in above a(iv). Then a convex lens of focal length 10 cm kept 10 cm rightward the convex lens mentioned above and a concave lens is kept 5 cm leftward to the first convex lens as shown in the figure and obtained a clear image of the first object on the screen.



i. Calculate the distance to the image formed due the second convex lens from the screen.

ii. Calculate the focal length of the concave lens.

iii. The screen is now shifted 15 cm to the right. keeping the other items in their original positions, another lens is placed in contact with the concave lens to form a lens combination. Calculate the power of the lens that must be used to form a clear image of the original object on the screen.

(c) A compound microscope is formed using two convex lenses of focal length of eyepiece lens f_e and focal length of objective lens f_o. The minimum distance of distinot vision is D.

i. Draw the ray diagram of the normal adjuctment of the microscope

ii. Obtain an expression for the angular magnification

iii. If f_0 = 5 cm, fe = 10 cm, D = 25 cm and the distance to the micro object from the objective is 6 cm. Calculate the angular magnification for the normal adjustment.

(d) An astronomical telescope is formed using the two convex lenses mentioned c(iii) above.

i. Draw the ray diagram for the normal adjustment of the telescope.

ii. What is meant by "eye ring" of the telescope .

iii. Calculate the distance to the eye ring from the eye piece lens when the telescope is at its normal adjestment.

iv. Calculate the angular magnifiÊtion of the telesco± at normal adjñtment

07. (a) i. Define the coefficient of viscosity of a fluid and write its units and dimensions.

ii. Write an expression for the stoke's law and identify the physical quantity you used.

(b) Consider a small sphere falling down vertically through a viscous fluid.

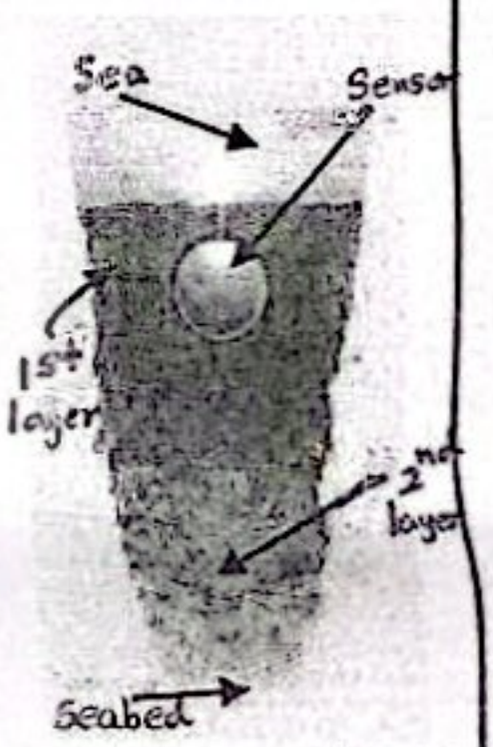
i. Draw the forces acting on the sphere at a certain instance and introduce them.

ii. Derive an expression for the terminal velocity (V_t) of the sphere by means of the equlibrium when it reaches terminal velocity. The radius of the sphere r, density of the sphere meterial ρ , density of the liquid σ and coefficient of viscosity of the fluid. η .

iii. Why is the sphere allowed to fall through a large spread of liquid.

iv. What is a small sphere selected for this?

(c) Dr. Aravinda, a remowned ocenographer has developed a small sensor featuning a specialized metal sphere to explore the bottom of the ocean. The radius of this sensor is 1.0×10^{-3} mand density of the material is 8400 kg m^{-3} . He releases this sensor into seawater. At the begining of its journey, it passes through a water layer near the surface with a density of 750 kgm^{-3} and a coefficient of viscosity of 0.2 Pas Later, he observes it entering a very deep, high - pressure cold water layer with a density of 1470 kg $m^{-3}$and a higher coeffient of viscosity 0.7 Pas.



i. Calculate the terminal velocity (V_t) attained by the sphere as it travels through first fluid.

ii. Assuming that the velocity of the sphere remains V1 immediately after entering the second fluid, find the resultant force acting on the sphere (F_{net}) at that moment.

iii. Calculate the acceleration of the sphere just after entering the second fluid.

iv. Find the new terminal velocity (V_2) reached by the sphere after traveling through the second fluid for a long time and hence calculate ratioV_1/V_2 .

(d) A scientist working at a high-tech research institute is studying how a special liquid used liquid crystal displays flows as a very thin layer between two plates. The experiment requires glass plate with an area of 0.2m^2 to drag along an oil layer at a constant speed of 0.4 m s^{-1} Since the gap between the plates is 0.02m, the experiment is conducted by taking into accoun the viscosity of the oil as well as the surface tension of 0.07 N m^{-1} present at the edges of the liquid that are exposed to the air. (0.2 Pa s)

i. What is the viscous force here ?

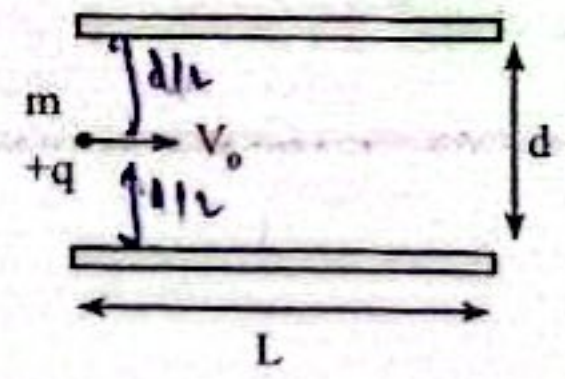
ii. Calculate the surface tension force of the liquid.

iii. Calculate the total force acting of the plate.

iv. Express the effect of the force due to surface tension as a percentage of the total force.

v. Explain the behavior of viscous force and force due to surface tension when the gap of the plates becomes very small.

08. (a) A particle of mass m and charge +q enters a uniform electric field with a velocity v_0. This electric field is created by two charged plates of length L, kept at a distance d from each other, having a potential difference V. The particle is projected along the middle between the plates as shown in the figure. Neglect the gravitational force acting on the particle.



i. Obtain an expression for the electric force F acting on the particle in terms of V, d, and q.

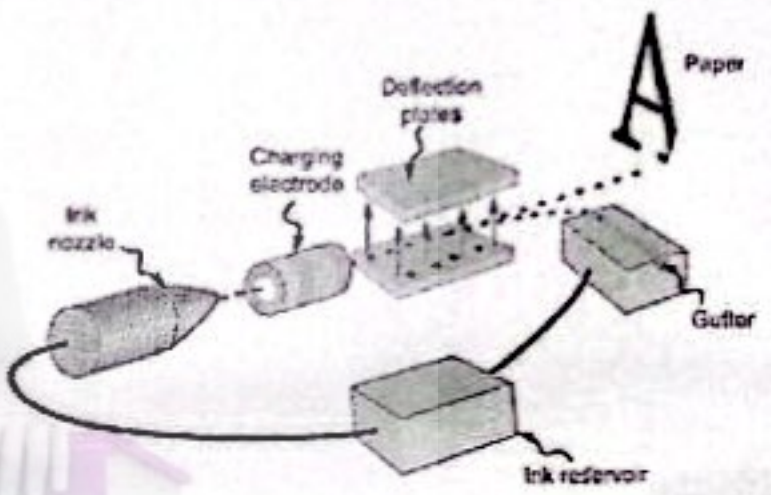
ii. Obtain an expression for the acceleration a experienced by the particle between the plates in terms of V, d, q, and m.

iii. If the particle exits between the plates without colliding with them, obtain an expression for the time t spent by the particle within the electric field in terms of v_0 and L.

iv. Obtain an expression for the vertical displacement made by the particle when exiting the field in terms of V, d, q, v_0 and L.

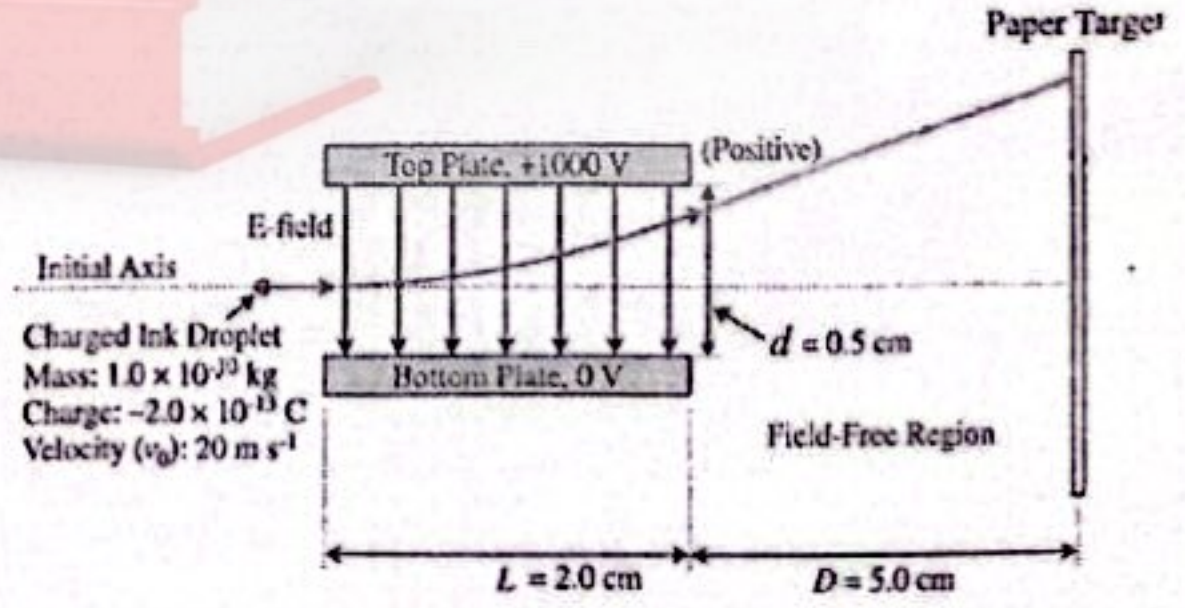
(b) An inkjet printer is a machine that prints by giving a charge to small ink droplets and positioning those ink droplets on a piece of paper.

As shown in the figure, a suitable charge is given to the ink droplets emitted by the nozzle using a charge electrode, and they are made to travel through an electric field.



The deflection made by the ink droplets within the electric field depends on the magnitude of the charge given, and thereby causes the ink droplets to travel to the required locations on the paper. The ink droplets not used for printing are deflected towards a gutter which collects and removes the ink.

- The mass of an ink droplet is 1×10^{-10} kg.
- The distance between the charged plates provided with a potential difference of 1000 V is 0.5 cm, and the length of a plate is 2 cm.
- Consider the region at a distance of 5 cm from the edge of the plates to the paper as a region free of an electric field.



i. Calculate the electric field intensity between the charged plates.

ii. Calculate the magnitude of the force acting on an ink droplet subjected to a charge of -2×10^{-13} C.

iii. Show that the gravitational force on the ink droplet can be neglected when compared to the electric force.

iv. Show that the above ink droplet, entering through the middle of the plates with a velocity of $20\ ms^{-1}$, does not collide with the charged plates.

v. Calculate the horizontal and vertical velocity components of the ink droplet when it exits from between the plates.

vi. Calculate the vertical distance the ink droplet has deflected from its original path of travel emitted by the nozzle, by the time it lands on the paper.

vii. When the charge given to the ink droplet is halved, is the deflected distance equal to half? Is it less than half? Is it more than half? Explain your reasons

09. **Answer either part (A) of part (B) only .**

PART (A)

(a) i. State kirchhoff's laws

ii. Discuss the relationship of those laws with conservation of charge and energy.

(b) The circuit given in fig. 1 consist of a battery of e.m.f. 6.8V and internal resistance r connected to lamp A and lamp B. I-V characteristics of lamps are shown in fig 2. The volt meter reading is 6.0 V at a certain instance..

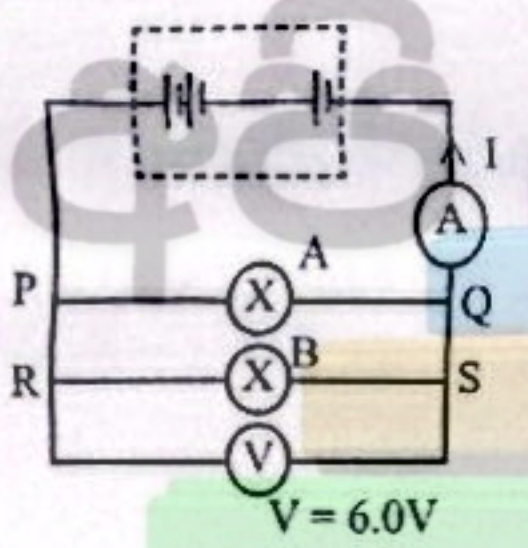


figure 1

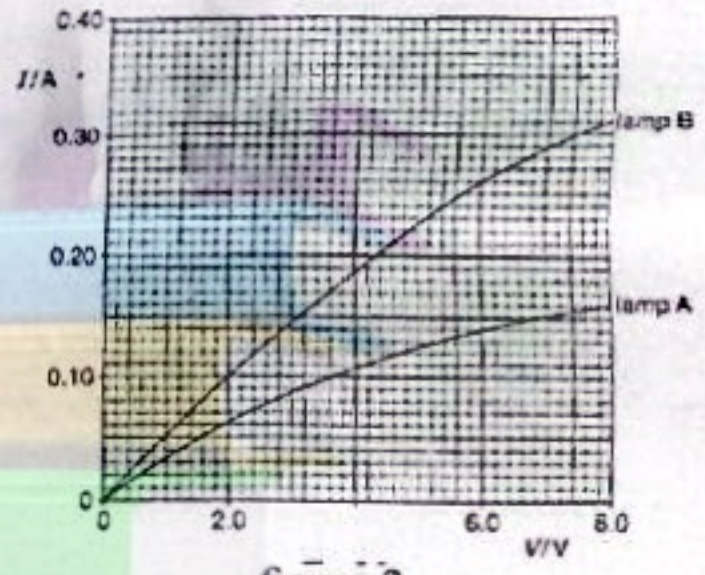


figure 2

i. What is the reading of ammeter A?

ii. I. Calculate the total power produced by the battery.

II. Calculate the electrical efficiency of the battery. (Give your anwer to one decimal place)

iii. Determine the internal resistance (r) of the battery..

(c) i. Determine the resistance of lamp A and lamp B at the instance (Give your answer to nearest whole number)

ii. A variable resistor Ru is connected in series with lamp B. Calculate the value of Rv required and current theory B to make consume the same power accross RS when they are operating with same terminal

iii. Explain why the I - V characteristic is non - linear If there lamps are filament bulbs.

(d) Now the battery mentioned in above (b) is replaced with a square coil of side length l = 0.05 m consisting of 100 turns which is placed in a uniform magnetic field, with its plane perpendicular to the field lines. The coil is then rotated 90° to a position where its plane is parallel to the field in 0.2 s.

i. If the lamps are operating with the same terminal potential difference 6V. What would be the flux density of the magnetic field.

ii. State the law that use to calculate the flux densty in words.

Part B

(a) State two ideal characteristice of an op-amp

(b) The circuit shown in the figure utilizes an ideal operational amplifier (op-Gmp) with a supply of ±9V. The inverty input can be switched between resistors R_A = 100 Ω and R_B = 10kΩ. The feedback resistor is R_f = 50kΩ)

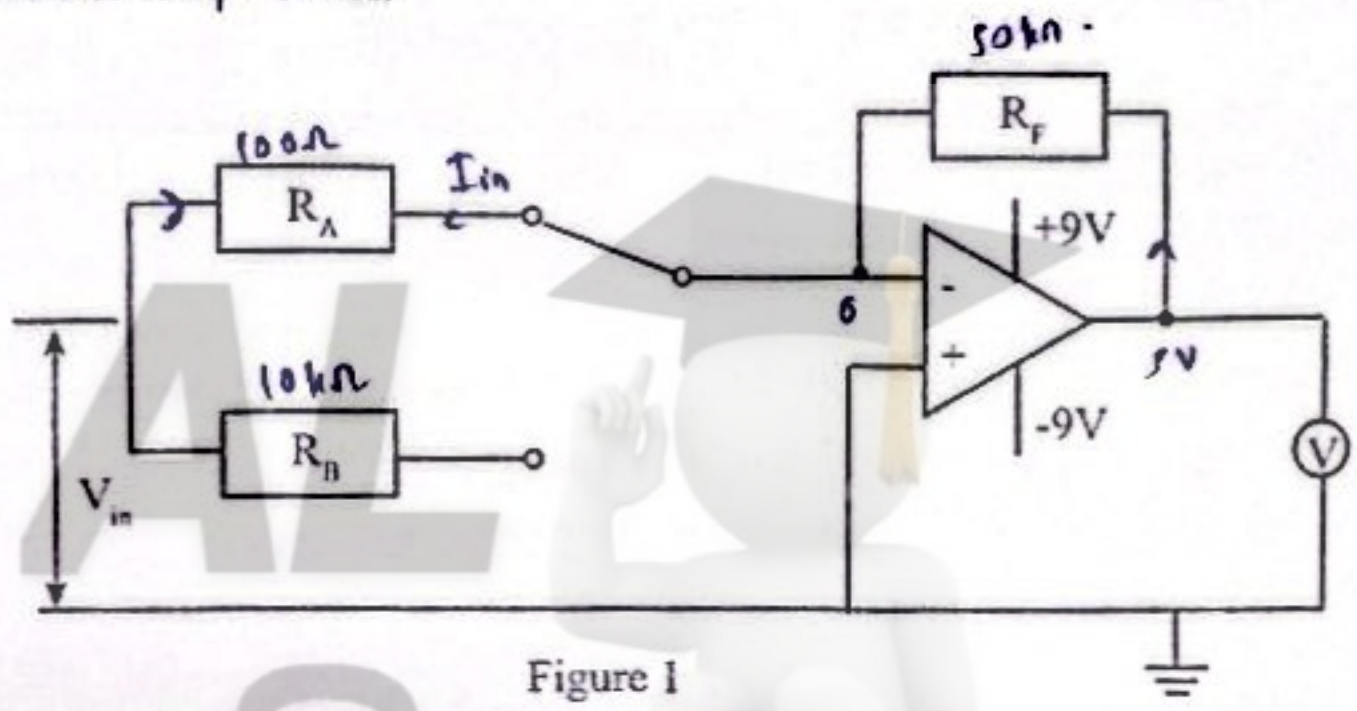


Figure I

(a) i. 1.

ii. 1. Describe the role of feed back resistor

2. What would happen to the out put voltage if this resistor is removed.

iii. 1. Explain qualitatinely how the switch allows the circuit to function as a variable gain amplifier

2. When the switch is moved from R_A to R_B discuss quantitatively the change in the magnitude of the output voltage, for same constant input V_{in}

(b) i. Copy the diagram on your answer script and mark the positive terminal of the voltmeter such that it yield a positive reading when V_{in} positive

ii. Calculate the required input potential V_{in} to achive a full - scale deflection of 5.0V on the volt meter when

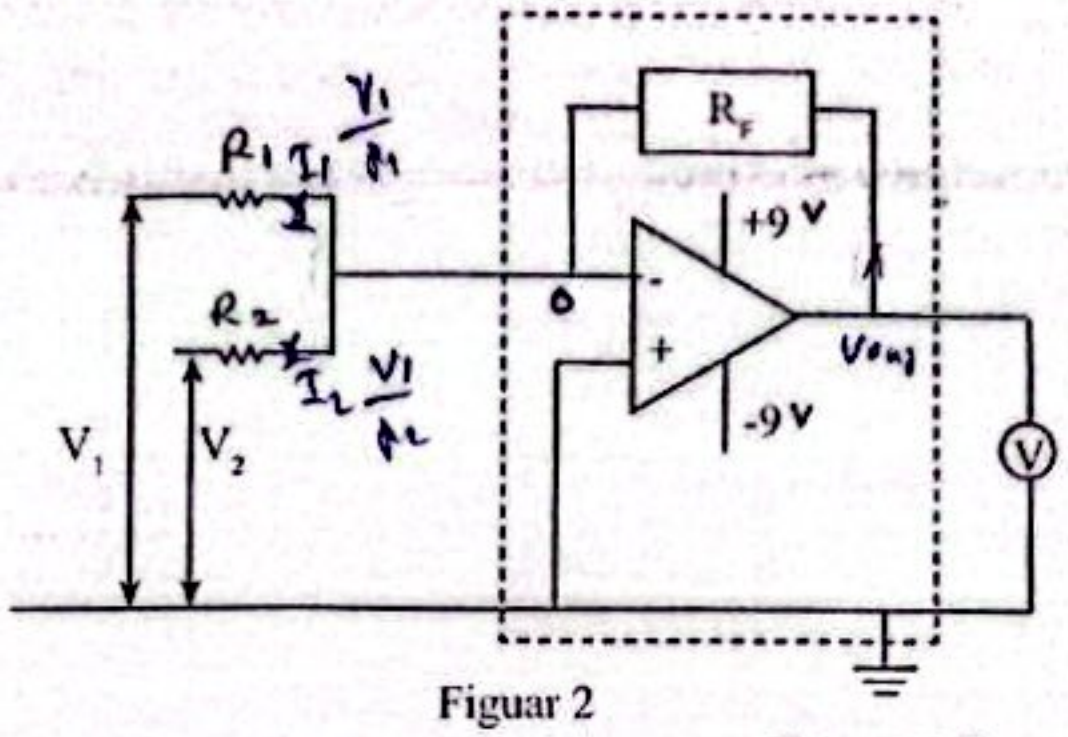
1. The switch connects to R_A

2. The switch connects R_B

iii. 1. For R_A configuration, calculate the magnitude of the input current I_{in} flowig through R_A when voltmeter reads 5.0V.

2. If the input V_{in} is a sinysodila signal defined by $V_{in}(t) = 0.05 \sin(100\pi t)$ derive the expression for the output voltage $V_{out}(t)$, when the circuit switced to R_B

(c) The circuit is modified to a summing amplifier by connecting two seperate voltage inputs (V_1 and V_2) through their own input resistors (R_1 and R_2) to the inverting input.



Figuar 2

i. Show that $V_{(out)}$ can be given as, $V_{(out)} = -R_f \left[\frac{V_1 + V_2}{R_1 + R_2}\right]$

ii. If the input volages are $V_1 = 0.5V$ and $V_2 = 1.0$ V and R_1 and R_2 are 10kΩ and = 20 kΩ respectively. Calculate the magnitute and polarity of the resulting output voltage V_{out}.

iii. It is required to design the circuit such that the output voltage $V_{(out)}$ follows the relation ship $V_{(out)} = -[2V_1 + 0.5V_2]$Determine the required R_1 and R_2 values.

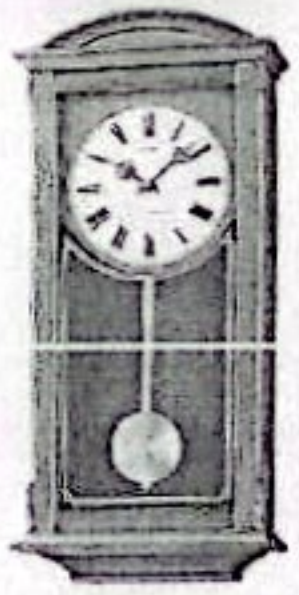
iv. If the input V_1 is constant 1.0 V and the input V_2 is a time - varying signal $V_2(i) = 2.0 \sin(50\pi t)$ obtain an expression for total output voltage $V_{(out)}(t)$

10. **Answer either part (A) of part (B) only**

PART (A)

(a) i. Define the linear expansivity of a solid

ii. A pendulum clock is designed to keep accurate time at a specific ambient temperature . Because the accurate time of the clock depends on the length of the pendulum and when the ambient temperature changes the length of the pendulum changes and an error occurs in the time shown in the clock face. If the ambient temperature is higher than the temperature at which the clock shows accurate time, will the time shown by the clock face be accurate, slow or fast? Explain



iii A certain pendulum clock is designed to show a time of 1 s on the clock face when its pendulum completes one oscillation. This clock shows accurate time at 20°C. This pendulum consist of a steel rod and a heavey metal bob. The weight of the rod can be neglected with compared to the weight of the bob

1. If the fractional change of the length of the rod is X when the ambient temperature rises up to 30°C, Calculate X (coeffient of liner expansion of steel is $1.2 \times 10^{-5}\,^{0}C^{-1}$)
2. If the fractional change of the period of oscillation of the pendulum when ambient temperature rises to 30°C is Y, obtain a relation between X and Y. (When $a << (1+a)^{1/2} = 1 + \frac{1}{2}a$)
3. What is the amount by which the time shown on the clock-face changes per day at ambient temperature of 30°C
4. What is the maximum change in ambient temperature so that the time difference accruing in the clock period does not exceed 1.00s.

5. Does the answer (a)(iii)4 above depend on the period of the simple pendulum ?

(b) A large balloon used for meteorological experiment has an opening at the lower end that is open to at mosphere and below that opening there is a combustion chamber to heat the air inside the ballon. There is basket below the combustion chamber used for storing goods.

The volume of a such balloon is 250 m^3 and the volume of the basket attached can be neglected compared to the volume of the balloon. Total mass of the balloon including the basket is 50 kg. The temperature of the air outside the balloon is 27°C and density of air is 1.2 $kgms^{-3}$

i. Calculate the buoyant force excrted on the balloon by the air outside it.
ii. What must the density of air inside the balloon before the balloon to just lift off from the ground ?
iii. What must the temperature of the air inside the balloon be, in degrees Celsius, at the moment the balloon lifts off from the ground
iv. At the temperature obtained in b(iii) above, what fraction of the air mass that was inside the balloon has been removed ?
v. When the temperature inside the balloon increases gradually it become 127°C at a certain instance. What would be the upward acceleration of the balloon at this instance.

PART (B)`

Two main interactions occur during X-ray examinations performed for diagnostic purposes. They are photo- electric effect and Compton scattering The photo electric effect is the main process that provides contrast in X-ray imagine.

X-rays interact with the atoms of the body tissues when they hits or passing through the body. In X-ray production, the total energy possessed by a photon is transfer to an internal sell electron (like K-shell) and elect it as photo electron. Due to this total energy absorption, dense structures with in the body appear more contrast in the image, and through that clear structural images can be obtained.

Since the electron in the inner shells are tightly bound, electron form the outer shells migrate to the inner shells, causing the emission of characteristic X-rays. This process involves less- energy, and because these are absorbed at the same point they do not contribute to the image signal.

The different in X-ray imaging mainly depends on the probability electric absorption, that is X-ray attenuation. This is mainly caused by two factors. Those are the atomic number (Z) and the energy ϵ of the X-ray photons. The X-ray attenuation is directly proportional to the cube of the atomic number (Z^3) and inversely proportional to the cube of the photon energy ($1/E^3$) in bones have higher X-ray attenuation than soft tissues. Therefore X-ray images of bones are more contrast.

∴ it appears brighter on the fluorescent screen. Therefore, as long as there is sufficient energy to pass through the patient's body, using photons with lower energy for a specific task is generally more advantageous.

(a) Write Einstein's photoelectric effect equation relating the maximum kinetic energy (K_{max}) of the emitted photoelectron, the wavelength λ, and the binding energy φ (work function) of the electron in the atom, when an Xray photon of wavelength λ collides with an electron in an inner shell of an atom.

(b) Explain how the photoelectric effect occurs within living tissues upon exposure to X-rays.

(c) Why do bones appear clearer (better visualized) than soft tissues on an X-ray photographic plate?

(d) (i) An X-ray photon with a wavelength of 2.2 Å can just barely liberate an electron in the first energy level of a Ca(Calcium) atom. Calculate the binding energy ϕ_1 for an electron in the first energy level of a Ca atom.

(ii) An electron transitions from the second energy level to fill the vacancy left by the electron removed from the first shell of the Ca atom. The binding energy for an electron in the second level of the Ca atom is ϕ_2, and due to this transition, a photon is produced with an energy equal to the difference between ϕ_1 and ϕ_2. If the wavelength of that emitted photon is 3.3 Å, calculate the binding energy φ_2 of the second shell.

(iii) Another X-ray photon having the exact same wavelength as mentioned in above (d)(i) liberates an electron located in the second energy level of a Ca atom. If this electron gains a kinetic energy of 6×10^{-16} J, calculate ϕ_2. Calculate the velocity of the electron.

(e) What are the factors affecting photoelectric absorption?

(f) If the average atomic mass for the bone part is 20 g mol^{-1} and the average atomic mass for the soft tissue part is 8 g mol^{-1}, calculate the ratio of photoelectric absorption between the bone part and the soft tissue part.

(g) In certain X-ray examinations, solutions like Barium or Iodine are introduced into the patient's body. Explain why.

(h) An X-ray machine can produce X-ray photons with energies of 30 keV and 60 keV. Compare the probability of these rays undergoing photoelectric interaction.

(i) Discuss the advantages and disadvantages of relatively reducing the photon energy when using X-rays for medica diagnosis.

USEFUL CONSTANTS:

Planck's constant, $h = 6.6 \times 10^{-34}$ Js, 1 Å = 10^{-10} m

Speed of light, $c = 3 \times 10^{8}$ ms^{-1}

Mass of an electron, $m_e = 9 \times 10^{-31}$ kg